Our study investigated solar energy (which included extra-terrestrial (ET) and global radiation) observed daily from six meteorological stations in Thailand from 1970-2010. Maximum values of global radiation for each day of the year, when subtracted from the corresponding ET value, provide estimates of the solar energy absorbed by the upper atmosphere, which we estimated to be close to 25% in Thailand. Using this assumption, we then fitted a simple statistical model to the percentage of solar energy absorbed by the lower atmosphere. This method provides an indication of the extent to which clouds and atmospheric particles block out the sun.
The Sun supplies energy to the Earth. Daily extra-terrestrial (ET) and surface (global) solar radiation energy were measured at six stations in Thailand from 1970 to 2010, when recording ceased. The levels vary from day to day and have a seasonal pattern, with higher values in summer (March to April in Thailand).

They also show time series auto-correlations, and some stations have stretches of missing data.
Components of global solar radiation

Surface solar radiation comprises **direct** (clear sky) and **diffuse** (scattered via clouds and other lower atmospheric components) radiation. These combine into **global** radiation using the formula \( R_G = R_D + R_B \cos(\zeta) \) where \( R_D \) is diffuse and \( R_B \) is direct radiation, and \( \zeta \) is the Sun’s **zenith** angle.

Differences between levels of ET and global radiation indicate the amount of solar energy absorbed by the atmosphere. It is important to investigate these differences to see how they may have changed with global warming in recent decades.

ET solar radiation is reduced first by the upper atmosphere and then by the lower atmosphere.

A measure of the reduction in the upper atmosphere is the **difference** between the ET radiation level for each day of the year at a given location and the maximum global radiation on the same day over many years. Further reduction in any given day may be attributed to clouds and other components of the lower atmosphere.
To high accuracy, the total daily solar energy reaching a horizontal surface above the Earth’s atmosphere - extra-terrestrial radiation ($R_E$) - depends only on two variables: latitude and season (day of year).

Assuming that the Earth is a sphere rotating around its axis with constant declination to its elliptical orbit around the Sun, SA Klein (Solar Energy vol 19, pp 325-329, 1977) gave the following formula for $R_E$ in mega joules/square metre.

$$R_E = (24/\pi)K \left(1 + 0.033\cos\left(\frac{2\pi d}{365}\right)\right)\left(\cos\phi\cos\delta\sin\omega + \omega\sin\phi\sin\delta\right)$$

In this formula, $\phi$ is the latitude angle, $d$ is the day of the year, $\delta$ is the Earth’s declination $23.45(\pi/360)\sin(2\pi(284+d)/365)$, $\omega$ is the sunset hour angle given by $\omega = \acos(-\tan\phi\tan\delta)$, and $K$ is the solar constant. Klein gave the value 4.871 MJ/m$^2$ for this constant but slightly higher values have been suggested by other authors.
Data from six stations in Thailand

Blue-coloured dots denote maximum daily surface global radiation recorded during 1970-2010. Five stations have latitudes close to 15°N, with Songkla further south. If K is 4.925, all ET radiation levels closely agree with the formula.

Daily maximum surface solar radiation levels are at least 25% lower than the ET levels over the period.
Let us assume that the proportion of ET solar radiation energy absorbed by the upper (above cloud) atmosphere is constant and equal to $P_0$, say. This assumption is reasonable because the atmosphere is similar everywhere on Earth, constrained only by the Earth’s gravity (although its density depends on latitude).

It follows that the amount of solar energy absorbed by other atmospheric components on a given day at any given latitude is $R_C = R_E (1 - P_0) R_G$. Using the formula for $R_E$ and observed values for $R_G$, we can now fit a statistical model to $R_C$.

For data observed from a given weather station, this model is a linear model taking the form

$$R_C = \text{factor(year)} + \text{factor(season)}.$$ 

To reduce the serial correlation between daily observations radiation levels, these are aggregated into 5-day averages. Missing data will also be reduced substantially as a result.
The year effects and season (month) effects given by the linear model are plotted below for each of the six meteorological stations where solar radiation observations were taken. The grey bands denote 95% confidence intervals for differences from the mean at each station.
Conclusions

Our results show that the estimated percentage of solar radiation energy absorbed by clouds and other bodies in the lower atmosphere varies with month of the year with patterns for different geographical locations in Thailand. However, while annual trends show variation, no overall increase or decrease over the 40-year period was evident.

In all six meteorological stations in Thailand where solar energy was recorded, very few days had sufficiently clear skies to admit the 75% of extra-terrestrial radiation available after absorption by the upper atmosphere, a finding that is difficult to explain unless the absorption percentage is around 70% rather than the 75% we assumed, in which case data for two stations from October-December are incorrect.

Further study is needed to understand how solar radiation is absorbed by the atmosphere.